LightHinge+
Additively manufactured lightweight engine hood hinge
Simulating manufacturing - the manufacturing division of MSC Software

- Supporting the optimization of metal-based manufacturing processes
- Manufacturing oriented process simulation
- Technology based on specially adapted MSC MARC non-linear finite element solver – SF-MARC

- more than 20 years of experience
- more than 70 experts
- more than 700 customers
LightHinge+ project partners

- **EDAG**
  - German automotive engineering supplier
  - 8,260 employees
  - 715 Mio € turnover

- **voestalpine**
  - Austrian metal material, metal parts & engineering supplier
  - 48,400 employees
  - 11.3 Billion € turnover

- **simufact**
  - German software company focused on manufacturing simulation
  - 70 employees
  - An MSC software company
LightHinge+ project share

- Topology optimization
- Part design
- Static stress justification

- Support structure design
- Build parameter selection
- Additive manufacturing

- Additive manufacturing simulation incl. load calibration
- Distortion compensation by pre-deformation
- Validation of distortion compensation
LightHinge+ project share Simufact

I • Calibration of manufacturing loads dependent on process parameters

II • Model setup in simufact additive software

III • Simulation & evaluation of the additive manufacturing process

IV • Create pre-deformed part geometry for distortion compensation

V • Validation of distortion compensation by optical measurement
LightHinge+ project share Simufact

Hinge function - Copyright EDAG Engineering

Size reference of the hinge - Copyright EDAG Engineering

Comparison hood hinge: Additive vs. traditional construction - Copyright EDAG Engineering
Calibration of manufacturing process loads

- Cantilever specimens with different scanning strategies have been printed by voestalpine.
- The cantilevers have been cut and the deformation measured.
- Deformations have been input into simufact additive.
- The inherent strains that reflect the manufacturing process loads have been calibrated.

Inherent strains are optimized until they reproduce the test results.
Model setup for AM simulation

- Import part geometry
- Import support structure geometries
- Select material from database – 316L steel
- Define process chain to be simulated (build part, cut from plate, remove supports)
- Mesh geometries with voxels

1200 k elements
600 k elements

0.5 mm voxel mesh
AM simulation of single parts

- Simulation of
  - Building the part
  - Cutting from plate
  - Removing support structures

- Calculation times
  - Lower bracket
    - 2d 13.6 hrs on 14 cores
  - Upper bracket
    - 8.6 hrs on 8 cores

- Total displacement shown
AM simulation of single parts

- Simulation of
  - Building the part
  - Cutting from plate
  - Removing support structures

- Calculation times
  - Lower bracket
    - 2d 13.6 hrs on 14 cores
  - Upper bracket
    - 8.6 hrs on 8 cores

- Equivalent stress shown
AM simulation of real-life build space

- Actually six parts are manufactured simultaneously
  - 3 lower brackets
  - 3 upper brackets
- Simulation of
  - Building the parts
  - Cutting from plate
  - Removing support structures
- Total displacement shown
- For demonstration only!
- Single part analysis to be preferred
AM simulation results

- Total displacement shown
- Model is stabilized as it loses its reference after being cut from the plate
- Therefore displacement values are not unique, but dependent on relative position to original mesh
- Nevertheless prediction of part distortion unaffected
AM simulation results

- Effective respectively equivalent stresses shown
- Stresses are calculated based on non-linear elastic-plastic material model with realistic stress-strain relationship (flow curve)
- Yield stress at 585 MPa
  - Plastification leads to permanent deformation = distortion
- Ultimate strength is 685 MPa
  - No failure expected
Pre-deformed shape for distortion compensation

Simulated distortion

Invert distortion with negative scale factor

Export pre-distorted STL

- Simulated distortion is inverted
- Inverted distortion is mapped on surface STL
- Pre-distorted STL is exported
- Exported STL was used for optimized AM of distortion compensated parts

NB: shown distortions are overscaled by a factor of 10 for better visualization
Validation by optical measurement

With kind support from...
LightHinge+ lower bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
LightHinge+ lower bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
LightHinge+ lower bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
LightHinge+ lower bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
LightHinge+ upper bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
LightHinge+ upper bracket

Original distortion of manufactured part vs. CAD

Distortion compensated based on simulation results
Conclusions

- Significant reduction of the initial distortion up to 80% thru AM simulation.
- Maximum distortion was cut by half from about 1.5 mm to 0.75 mm.
- Further improved results possible by additional simulation iterations. (Only one in project.)
- No necessity for building costly and time consuming trial parts.
- No necessity for expensive compensation of distortion based on optical measurements.
- AM part can already be within the given tolerances after the first build job.
- Manufacturing time and costs are reduced dramatically!
Time for Questions